



NSRL-3 RUN

FINAL REPORT

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<http://www.bnl.gov/medical/NASA/NASA-home%20frame.htm>

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EXECUTIVE SUMMARY

During the summer of 2004, a series of radiobiological and physics experiments were performed using the NASA Space Radiation Laboratory to accelerate iron and proton beams (NSRL-3). These experiments were part of the third NSRL scientific run sponsored by NASA's Space Radiation Health Program (SRHP) heavy ion radiobiology research program at BNL.

A total of 24 proposals were approved by the BNL' SACR to participate in the NSRL-3 run. Twenty institutions from the United States and 2 from foreign countries (Japan and Italy) were represented, totaling 78 users. More than 800 biological samples were exposed at the NSRL beam line, employing 286 hours of beam time (40 hours for in vivo studies, 74.5 hours for in vitro studies and 66 hours for physics experiments). In addition, 6 hours were used for beam development and, 93.5 hours for set-up and dosimetry. A total of 6.5 hours of beam time were lost due to accelerator related problems.

During NSRL-3, Booster provided iron (0.577 and 0.969 GeV/nucleon, LET: 176.1 and 151.1 keV/ μ m) and Protons (1 GeV/n, LET: 0.021 keV/ μ m) beams for biology and physics experiments. The dose/rates used were as low as 0.1 cGy/min and as high as 2000 cGy/min. The spill rate employed was 20 for Fe, with duration of 400 msec/spill. The spill fluence was (particles/spill) 3×10^9 (max) and 500 (min). Square beam spots as big as 20 x 20 cm and small as 1 x 1 cm was employed for biology and physics experiments. For the first time Tandem-Booster-NSRL complex was able to deliver a mix field composed by iron and protons with energies of 1 GeV/n with a steady and repeatable switching from protons to iron. The longest switching time was 7 minutes and the shortest was 1 minute. The typical one was ~2 minutes. This new capability will offer more realistic sample exposures using cells and animals eventually.

Tandem-Booster set-up started on June 6 with the transport and circulation of p beams at the NSRL complex. Beam was tuned into cave on June 7. 1000 MeV/n p beams were available for tuning on June 7. The next several shifts were spent on beam characterization and dosimetry in preparation of biological and physics experiments. Biology studies started on the morning of June 8 using p beams (Cucinotta-Wu, NASA) and proceeded through June 10. On June 11, AGS-Booster tuned 1 GeV/n iron beams for biology and physics studies ending on June 23. From June 24 to late June 26, NSRL delivered 0.6 GeV/n iron beams for a limited series of biological experiments. On the early morning of June 28, Tandem-Booster complex delivered iron ions and protons 1 GeV/n to test fast delivery of mixed ions for physics and biology. A series of biological experiments using mixed field were completed on the evening of June 30 (B. Sutherland). NSRL-3 officially ended at 1900 pm, June 30, 2004.

One of the NSRL-4 highlights, was the commencement of the new NASA sponsored Space Radiation Summer School on June 1, 2004. The school made use of the NSRL facilities to train 11 students selected by NASA, in the basic concepts of high-LET radiobiology and how to plan and execute an experiment using NSRL. The students and faculty employed 13 hour of beam time to expose cell, animals and detectors to iron ions.

NSRL-3 Projects Reviewed by the BNL's Scientific Advisory Committee in Radiobiology (SACR):

Proposal	PI	Funding	NSRL-3 Participation
B3	Cucinotta	NASA	Yes
B7	Rabin	NASA	Yes
B65	Vazquez	NSBRI	Yes
B66	Narici	ISA	Yes
B73	Sutherland	DOE/NASA	Yes
N88	Sutherland	NASA	Yes
N89	Held	NASA	Yes
N91	Rydberg	NASA	Yes
N95	Story	NASA	Yes
N99	Zhao	NASA	Yes
N103	Barcellos-Hoff	NASA	Yes
N104	Weil/Ullrich	NASA	Yes
N105	Chatterjee	NASA	No
N108	Pecaut	NASA	Yes
N113	Pecaut	NASA	Yes
N115	Bacher	NASA	No
N118	Miller	NASA	Yes
N119	Archambeau	NASA	No
N121	Moyer	NASA	Yes
N122	Nelson	NASA	Yes
N123	Radeka	NSBRI	Yes
N124	Li	NASA	Yes
N126	Kennedy	NSBRI	Yes
N128	Vazquez	NASA	Yes

NSRL-3 PARTICIPANTS

Exp.	Participants	Affiliation	Title
B-3	F. Cucinotta* K. George H. Wu N. Desai	NASA, Johnson Space Center, TX “ “ “	Ph.D, Principal Investigator Senior Research Associate Ph.D., Co-Worker B.S., Co-Worker
B-7	B. Rabin A. Carey K. Carhill	UMBC, Baltimore, MD “ “	Ph.D, Principal Investigator B.A., Co-worker B.A., Co-worker
B-52	A. Gewirtz* B. Sutherland P. Bennett M. Naidu D. Roy M. Hada J. Sutherland D. Monteleone J. Trunk	University of Penn. School of Medicine, PA BNL, Biology Dept., Upton, NY “ “ “ “ “ “ “	Ph.D, Principal Investigator Ph.D, Co-Principal Invest. M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker
B-65	M. Vazquez P. Guida A. Billups K. Nojima	Brookhaven National Laboratory, NY “ “ NIRS/HIMAC, Japan	M.D, Ph.D, Principal Invest. Ph.D, Co-Worker B.S., Co-Worker Ph.D, Co-Worker
B-66	L. Narici V. Bidoli F. Belli S. Carozzo	University of Rome 'Tor Vergata' “ “ “	Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
B-73 N-88	B. Sutherland P. Bennett M. Naidu D. Roy M. Hada P. Kumar J. Sutherland D. Monteleone J. Trunk	Brookhaven National Laboratory, NY “ “ “ “ “ “ “ “	Ph.D, Principal Investigator M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker
N-89	K. Held H. Yang V. Anzenberg	Massachusetts General Hospital/ Harvard Medical School “	Ph.D, Principal Investigator Ph.D., Co-worker B.S., Co-worker
N-91	B. Rydberg	LBNL, Berkeley, CA	Ph.D, Principal Investigator
N-95	M. Story U. Giri	University of Texas, MD Anderson, TX “	Ph.D, Principal Investigator Ph.D., Co-worker
N-99	Y. Zhao C. Piao	Columbia University, NY “	Ph.D., Principal Investigator Ph.D., Co-worker
N-103	M. Barcellos-Hoff* B. Rydberg S. Costas L. Ding	LBNL, Berkeley, CA “ “ “	Ph.D., Principal Investigator Ph.D., Co-worker Ph.D., Co-worker Ph.D., Co-worker
N-104	M. Weil R. Ullrich F. Ray P. Genik M. Callan	Colorado State University, CO “ “ “ “	Ph.D, Principal Investigator Ph.D., Co-Principal Invest. Ph.D., Co-worker Ph.D., Co-worker B.S., Co-worker

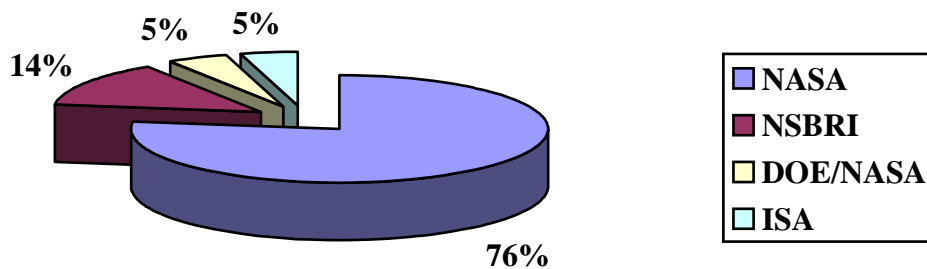
Exp.	Participants	Affiliation	Title
N-108 N-113	M. Pecaut A. Smith A. Mosley	Loma Linda University, CA “ “	Ph.D, Principal Investigator B.S, Co-Worker B.S, Co-Worker
N-118	J. Miller C. Zeitlin L. Heilbroin M. Kristal	LBNL, Berkeley, CA “ “ NASA Langley Research Center, VA	Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
N121	M. Moyer S. Righthmar	Loma Linda University, CA “	Ph.D, Principal Investigator B.S, Co-Worker
N-122	G. Nelson T. Jones A. Smith S. Rightnar C. Perez	Loma Linda University, CA “ “ “ “	Ph.D, Principal Investigator B.S., Co-Worker B.S., Co-Worker B.S., Co-Worker B.S., Co-Worker
N-123	V. Radeka B. Yu J. Mead	Brookhaven National Laboratory, NY “ “	Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker
N-124	C-H. Li Bin Yan Qi Chen Shanling Liu	Duke University, NC “ “ “	Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
N-126	A. Kennedy J. Ware X. Wan J. Guan Z. Zhou J. Stewart J. Donahue	University of Pennsylvania, PA “ “ “ “ “ “	Sc.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker M.S., Co-Worker M.S., Co-Worker M.S., Co-Worker
N-128	M. Vazquez G. Nelson A. Kronenberg A. Rusek P. Guida O. Rice R. Vlkolinski R. Sun B. McKnight L. Rein C. Burrell P. Pandya V. Serra E. Lloyd L. Thomas V. Anzenberg T. Jones A. Smith	Brookhaven National Laboratory, NY Loma Linda University, CA LBNL, Berkeley, CA Brookhaven National Laboratory, NY “ “ Scripps Research Institute / NSCOR, CA Washington University / NSCOR, WA North Carolina A&T, NC Johnson Space Center, TX Loma Linda University, CA “ “ “ Southampton College, NY MIT / Mass General Hospital, MA Loma Linda University, CA “	Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Research Associate Grad Student Grad Student Grad Student Research Assistant Grad Student Grad Student B.S., Co-Worker B.S., Co-Worker

***Not Present During Actual Run**

NSRL-3 PARTICIPANTS STATISTICS

PARTICIPANTS	NSRL-3
Ph.D., Principal Investigators	16
M.D., Ph.D., Principal Investigators	1
Ph.D., Co-Principal Investigators	1
Sc.D., Principal Investigators	1
Co-Workers	
Ph.D.	35
Graduate Students	5
M.S.	4
B.S.	10
B.A.	2
Research Assistant	1
Research Associate	1
Senior Research Associate	1
Total:	78

RESEARCH PROJECT SPONSORS:



PARTICIPANT INSTITUTIONS

NASA related centers/institutes (4)

- NASA, Johnson Space Center, TX
- National Space Biomedical Research Institute, TX
- NASA Langley Research Center, VA
- NASA NSCORTs

National Laboratories/Institutes (2)

- Brookhaven National Laboratory, NY
- Lawrence Berkeley National Laboratory, CA

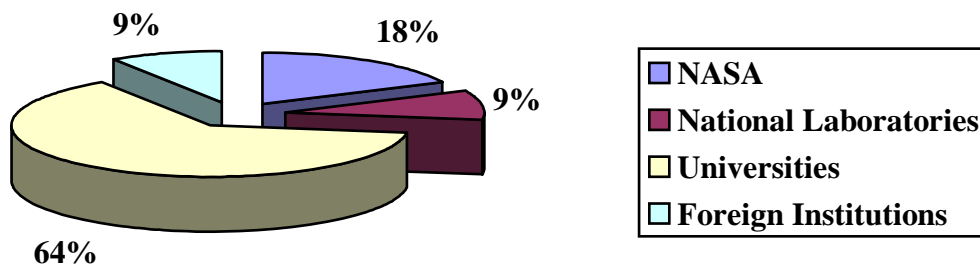
Universities (14)

- UMBC, Baltimore, MD
- University of Penn. School of Medicine, PA
- Massachusetts General Hospital/ Harvard Medical School, MA
- University of Texas, MD Anderson, TX
- Columbia University, NY
- Colorado State University, CO
- Loma Linda University, CA
- Duke University, NC
- University of Pennsylvania, PA
- North Carolina A&T, NC
- Southampton College, NY
- MIT / Mass General Hospital, MA
- Scripps Research Institute / NSCOR, CA
- Washington University / NSCOR, WA

Foreign Institutions (2)

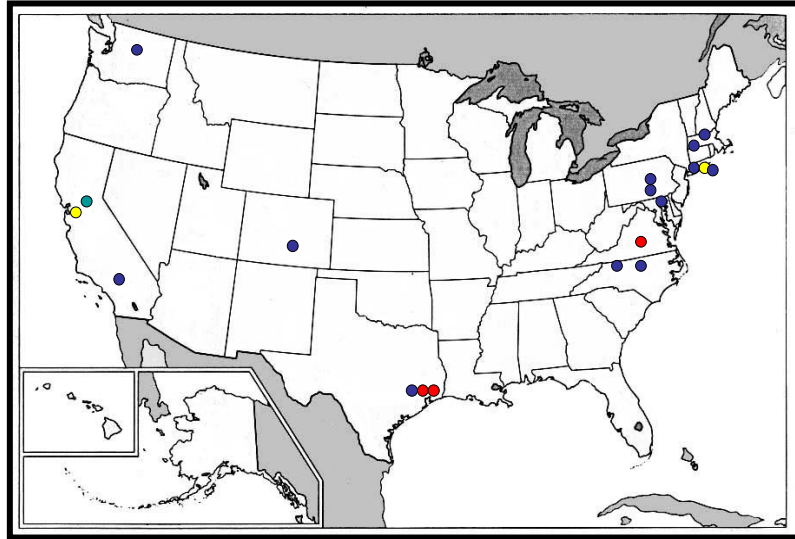
- NIRS/HIMAC, Japan
- University of Rome 'Tor Vergata'

INSTITUTIONS STATISTICS:



U.S. Participant Institutions and State Distribution

- NASA Related Centers
- National Laboratories
- Universities
- Privates Institutions



California

- Lawrence Berkeley National Laboratory, Berkeley
- Loma Linda University, Loma Linda
- Scripps Research Institute / NSCOR, CA

Colorado

- Colorado State University, Fort Collins

Maryland

- UMBC, Baltimore

Massachusetts

- Massachusetts General Hospital/ Harvard Medical School
- MIT / Mass General Hospital, MA

New York

- Brookhaven National Laboratory, Upton
- Columbia University, New York
- Southampton College, Southampton

North Carolina

- North Carolina A&T,
- Duke University, NC

Pennsylvania

- University of Pennsylvania School of Medicine, Philadelphia
- University of Pennsylvania, Philadelphia

Texas

- NASA Johnson Space Center, Houston
- National Space Biomedical Research Institute, Houston
- University of Texas MD Anderson

Virginia

- NASA Langley Research Center

Washington

Washington University / NSCOR

NSRL-3 PROTON 1 GeV/n RUN DESCRIPTION

RUN DATES

Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	06/07	0700	06/07	0700
Run end	06/10	2330	06/10	1930
Tuned into cave	06/06	1700	06/06	TBD
Beam delivered for Biology				
p 1 GeV/n	06/08	0900	06/08	0930
End run	06/10	1830	06/10	1930

BEAM TIME DESCRIPTION (hours)

Total Clock Time	(from 06/07 0700 to 06/10 1930)		64
Total Beam-on time			60.5
Total Beam-off time			3.5
Beam Time for Biology			
p 1 GeV/n In Vitro Studies	27.0		
p 1 GeV/n In Vivo Studies	2.5		
Sub-total		29.5	
Beam Time for Physics	8		
Sub-total		8	
Set Up Time/Spill Structure	20.0		
Sub-total		20.0	
Set Up Time for Beam Develop.	0		
Sub-total		0	
MCR Wrap-Up Time	3.0		
Total		3.0	
Totals			60.5
Contingency T. Planned	4		
Contingency T. Used	2		

NSRL-3 IRON 1 GeV/n RUN DESCRIPTION

RUN DATES

Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	06/11	0700	06/11	0700
Run end	06/23	2030	06/23	1600
Tuned into cave	06/11	0700	06/11	1148
Beam delivered for Biology				
Fe 1 GeV/n	06/11	1300	06/11	1400
End run	06/23	2030	06/23	1600

BEAM TIME DESCRIPTION (hours)

Total Clock Time	(from 06/11 0700 to 06/23 1600)		146.5
Total Beam-on time			143.5
Total Beam-off time			3.0
Beam Time for Biology			
Fe 1 GeV/n In Vitro Studies	28.0		
Fe 1 GeV/n In Vivo Studies	18.0		
Sub-total		46.0	
Beam Time for Physics	58.0		
Sub-total		58.0	
Set Up Time/Spill Structure	27.0		
Sub-total		27.0	
Set Up Time for Beam Develop.	6.0		
Sub-total		6.0	
MCR Wrap-Up Time	6.5		
Total		6.5	
Totals			143.5
Contingency T. Planned	11.0		
Contingency T. Used	7.5		

NSRL-3 IRON 0.6 GeV/n RUN DESCRIPTION

RUN DATES

Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	06/24	0700	06/24	0700
Run end	06/27	0200	06/26	1830
Tuned into cave	06/24	0600	TBD	TBD
Beam delivered for Biology				
Fe 0.6 GeV/n	06/24	1100	06/24	1230
End run	06/27	0200	06/26	1830

BEAM TIME DESCRIPTION (hours)

Total Clock Time	(from 06/24 0700 to 06/26 1830)		34.5
Total Beam-on time			34.5
Total Beam-off time			0.0
Beam Time for Biology			
Fe 0.6 GeV/n In Vitro Studies	4.0		
Fe 0.6 GeV/n In Vivo Studies	19.5		
Sub-total		23.5	
Beam Time for Physics	0.0		
Sub-total		0.0	
Time for Beam Develop.	0.0		
Sub-total		0.0	
Set Up Time/Spill Structure	9.5		
Sub-total		9.5	
MCR Wrap-Up Time	1.5		
Total		1.5	
Totals			34.5
Contingency T. Planned	3.0		
Contingency T. Used	0.0		

NSRL-3 PROTON-IRON 1 GeV/n RUN DESCRIPTION

RUN DATES

Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	06/29	0700	06/29	0700
Run end	06/30	1700	06/30	1900
Tuned into cave	06/28	TBD	06/28	1800
Beam delivered for Biology				
Fe 0.6 GeV/n	06/29	0900	06/29	1200
End run	06/30	1600	06/30	1900

BEAM TIME DESCRIPTION (hours)

Total Clock Time	(from 06/23 0700 to 06/30 1900)		41.0
Total Beam-on time			41.0
Total Beam-off time			0.0
Beam Time for Biology			
In Vitro Studies	15.5		
In Vivo Studies	0.0		
Sub-total		15.5	
Beam Time for Physics	0.0		
Sub-total		0.0	
Time for Beam Develop.	0.0		
Sub-total		0.0	
Set Up Time/Spill Structure	24.5		
Sub-total		24.5	
MCR Wrap-Up Time	1.0		
Total		1.0	
Totals			41.0
Contingency T. Planned	3.0		
Contingency T. Used	3.0		

NSRL-3 FINAL RUN DATES

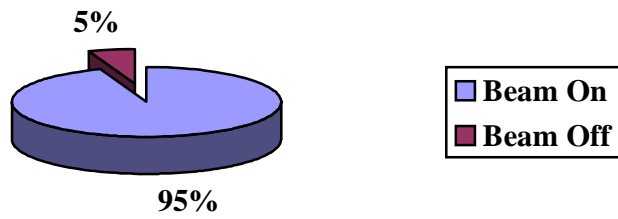
Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	06/07	0700	06/07	0700
Run end	06/30	1700	06/30	1900
Tuned into cave	06/06	1700	06/06	TBD

TOTAL BEAM TIME DESCRIPTION (hours)

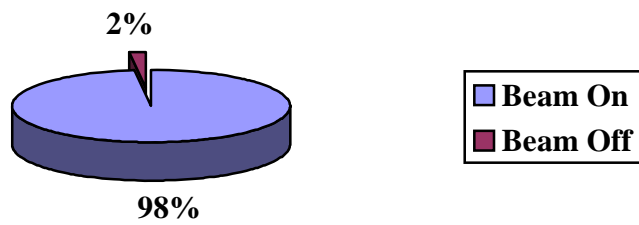
Planned Total Clock Time	(from 06/07 0700 to 06/30 1700)	309
Actual Total Clock Time	(from 06/07 0700 to 06/26 1900)	286
Total Beam-on Time		
p 1 GeV/n	60.5	
Fe 1 GeV/n	144.0	
Fe 0.6 GeV/n	34.5	
P + Fe 1 GeV/n	41.0	
Total		280.0
Total Beam-off time		
p 1 GeV/n	3.5	
Fe 1 GeV/n	3.0	
Fe 0.6 GeV/n	0.0	
P + Fe 1 GeV/n	0.0	
Total		6.5
Total Beam Time for Biology		
In Vivo Studies	40.0	
In Vitro Studies	74.5	
Total		114.5
Beam Time for Physics	66.0	
Total		66.0
Set Up/Spill Structure Time	81.0	
Total		81.0
Beam Development Time	6.0	
Total		6.0
MCR Wrap-Up Time	12.0	
Total		12.0
Totals		279.5
Contingency T. Planned	20.0	
Contingency T. Used	9.5	

DESCRIPTIVE STATISTICS

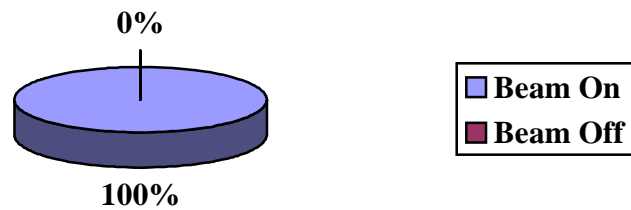
- **P 1 GeV/n BEAM AVAILABILITY**



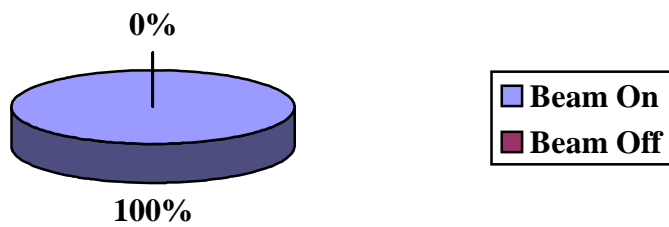
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- **FE 0.6 GeV/n BEAM AVAILABILITY**

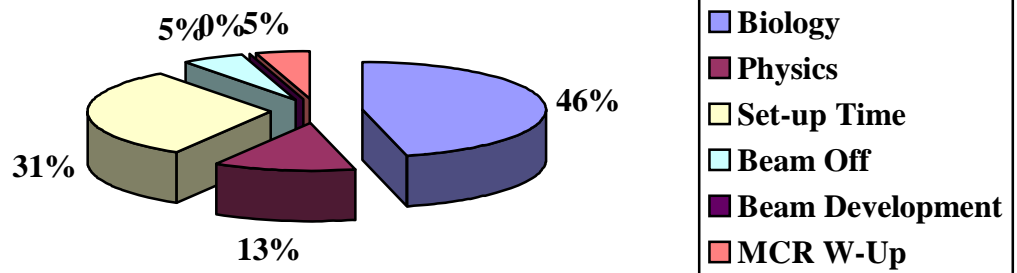


- **FE+P 1 GeV/n BEAM AVAILABILITY**

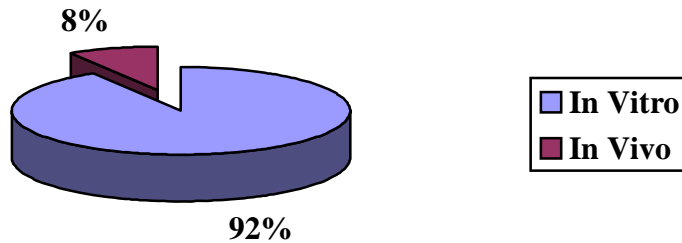


PROTON RUN:

- P 1 GeV/n DISTRIBUTION OF BEAM TIME USAGE:

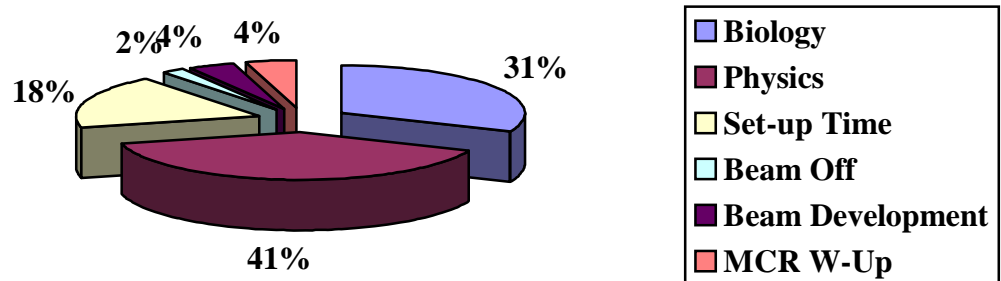


- P 1 GeV/n DISTRIBUTION OF BEAM TIME FOR BIOLOGY:

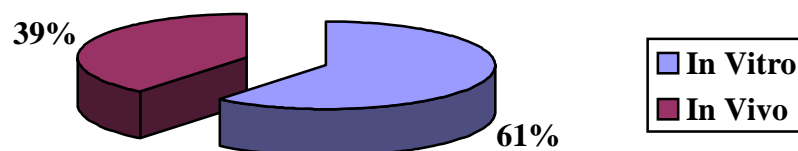


IRON ION RUN

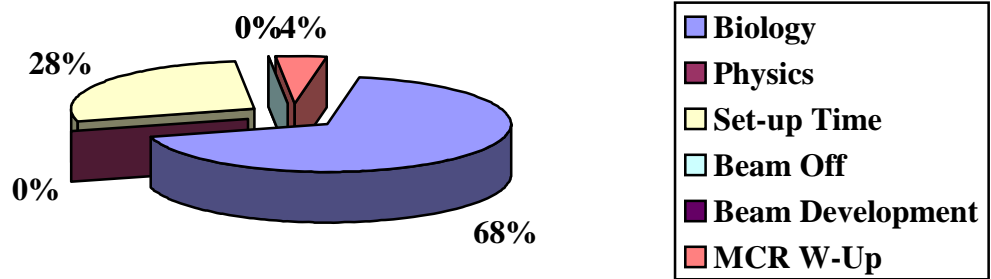
- FE 1 GeV/n DISTRIBUTION OF BEAM TIME USAGE:



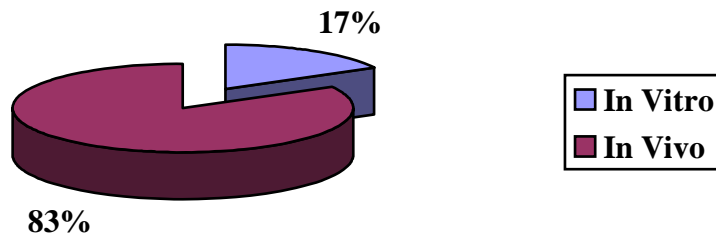
- FE 1 GeV/n DISTRIBUTION OF BEAM TIME FOR BIOLOGY:



- **FE 0.6 GeV/n DISTRIBUTION OF BEAM TIME USAGE:**

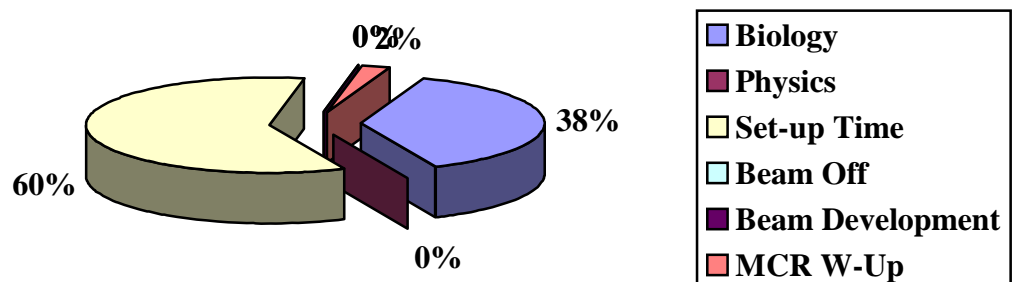


- **FE 0.6 GeV/n DISTRIBUTION OF BEAM TIME FOR BIOLOGY:**

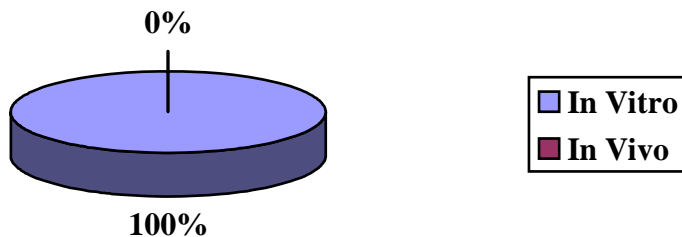


MIX FIELD RUN: IRON-PROTON RUN

- **FE+P 1 GeV/n DISTRIBUTION OF BEAM TIME USAGE:**

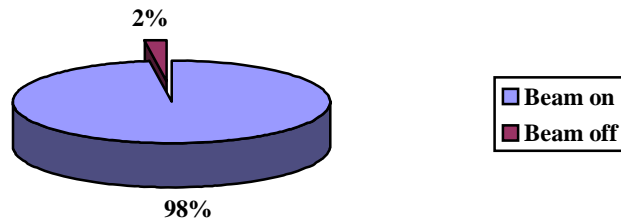


- **FE+P 1 GeV/n DISTRIBUTION OF BEAM TIME FOR BIOLOGY:**

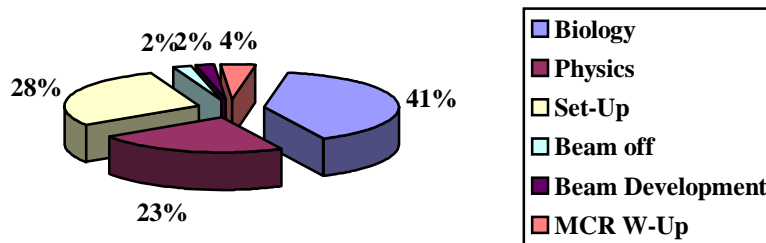


NSRL-3 TOTAL BEAM TIME SUMMARY

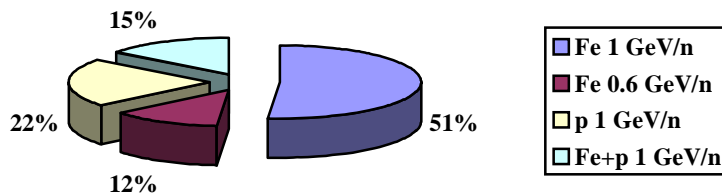
- TOTAL BEAM AVAILABILITY:**



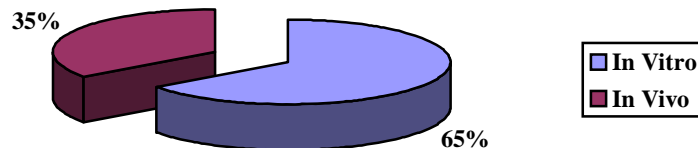
- DISTRIBUTION OF BEAM TEAM USAGE:**



- DISTRIBUTION OF BEAM TIME AVAILABLE BY SPECIES AND ENERGIES:**



- DISTRIBUTION OF BEAM TEAM FOR BIOLOGY EXPERIMENTS:**



BEAM CHARACTERISTICS

Ion	⁵⁶Fe²⁶		H¹
Fluence (particles/cm²/sec) Maximum on target Minimum on target	TBD	TBD	TBD
Spill Period (sec)	3.0	3.0	2.5
Spill rate (spills/min)	20	20	24
Spill length (msec)	400	400	400
Particles/spill Maximum Minimum	1000 500	1.0 x 10⁹ 500	5 X 10¹⁰ TBD
Beam Cut Off Accuracy	~ 0.5 %	~ 0.5 %	0.5 %
Actual Energy (MeV/n) Extracted On Target	600 577	1005 969.1	TBD TBD
Actual LET on Target (keV/μm)	176.1	151.4	0.024
Max. Dose Rate (Gy/min)/ Beam Size (cm x cm) 20 x 20 10 x 10 7 x 7 7 x 30 5 x 5 1 x 1	0.001	7.0 30.0 50.0	0.2 1.5
Total Dose (cGy) Maximum Minimum	400 15	400 0.1	2500 15

NSRL Mixed Field Test

After several hours of preparations and set-up, A. Rusek and colleagues were able to characterize the beams in order to maintain a steady and repeatable state upon switching from protons to iron. The same conditions were obtained for the iron to proton switch mode, but a more conservative approach was taken by making sure protons were established in the target area to satisfaction, and then put the sample in and exposed it to protons. We then left the sample on the target stand, switched to iron and delivered the desired dose to the sample. The longest switch time was 7 minutes. The shortest was 1 minute. The typical one was ~2 minutes. For each ion a separate setup file was used, so the calibration can change appropriately with the change of ions. So in fact, this was a mode switch of ALL systems

involved, from Tandem, through transfer lines, Booster, Extraction system, NSRL line and dosimetry. Using this new tune, Dr. Sutherland was able to exposed cell samples to different combinations of proton-iron sequences in order to explore the biological effects of this mixed field. Results obtained will expand the current NSRL capabilities in order to offer a unique capability to simulate in a more realistic way the space environment.

NSRL-3 EXPERIMENTERS AND RUN STATISTICS

Exp. ID	Principal Investigator	Ion & Energy	Beam Time Approved	Beam Time Used	Dose Range (cGy)	Dose/Rate (cGy/min)	Number of Samples
B-3	Cucinotta	Fe, 1 GeV/n	0	1.0	20-50	20	20
		p, 1 GeV/n	3.0	3.0	200-250	10-100	27
B-7	Rabin	Fe, 1 GeV/n	4.5	4.0	25-200	100	60
B-52	Gewirtz	p, 1 GeV/n	2.3	7.0	NA	NA	NA
N-65	Vazquez	P, 1 GeV/n	4.3	3.0	15-200	60-100	30
		Fe, 1 GeV/n	6.5	1.5	"	"	40
		Fe, 0.6 GeV/n	4.5	1.5	"	"	50
N-66	Narici	Fe, 0.6 GeV/n	16.0	18.0	NA	NA	NA
B-73	Sutherland	p, 1 GeV/n	4.5	7.0	NA	NA	NA
B-88	Sutherland	p, 1 GeV/n	2.5	7.0	NA	NA	NA
N-89	Held	Fe, 1 GeV/n	6.0	5.5	500 to	50	80
		p, 1 GeV/n	4.5	7.5	5000 part.	50	80
N-91	Rydberg	Fe, 1 GeV/n	6	2.5	25-150	100	8
		Fe, 0.6 GeV/n	2	1.0	25-150	100	8
N-95	Story	Fe, 1 GeV/n	2.5	6.5	25-200	120-280	37
N-99	Zhao	Fe, 1 GeV/n	1.5	1.0	30-100	200	14
N-103	Barcellos-Hoff	Fe, 1 GeV/n	12	5.5	23-300	100	61
N-104	Weil/Ullrich	Fe, 1 GeV/n	7.5	4.0	10-100	5-50	41
N-108	Pecaut	Fe, 0.6 GeV/n	3.0	1.0	0-400	100-200	18
N-113	Pecaut	Fe, 0.6 GeV/n	3	1.0	0.5-400	0.5 - 150	45
N-118	Miller	P, 1 GeV/n	8.0	8.0	NA	NA	NA
		Fe, 1 GeV/n	8.0	16.0			
		Fe, 0.6 GeV/n	12.0	0.0			
N-121	Moyers	Fe, 1 GeV/n	28.0	23.0	NA	NA	NA
N-122	Nelson	P, 1 GeV/n	2.5	2.5	100-2500	47	7
		Fe, 0.6 GeV/n	3.5	0.0			
N-123	Radeka	Fe, 1 GeV/n	17.5	15.0	NA	NA	NA
N-124	Li	Fe, 1 GeV/n	3.5	1.5	NA	NA	NA
N-126	Kennedy	Fe, 1 GeV/n	5.0	6.5	NA	NA	NA
		p, 1 GeV/n	7.0	6.5			
N-128	Vazquez	Fe, 1 GeV/n	12.0	13.5	30 -400	30 150	200
Totals			203.1	180.5	0.5-2500	0.5-280	~826

NSRL-3 PARTICIPANTS, EXPERIMENTAL SAMPLES AND ENDPOINTS

Exp.	Participants	Samples	Endpoints
B-3	Heavy Ion Induced Chromosome Damage and Biomedical Countermeasures F. Cucinotta (PI)	Human Lymphocytes, Human Fibroblasts, and Chinese Hamster cells	Chromosome damage, structure effects on DNA double strand break induction and repair.
B-7	Effects of Exposure to Heavy Particles B. Rabin (PI)	Sprague Dawley Rats	Behavioral paradigms and neurochemistry
B-52	Effect of Deep Space radiation on Human Hematopoietic Stem Cells. A. Gewirtz (PI)	Human bone marrow cells	DNA complex damages, DNA replication and apoptosis, gene expression
N-64	Risk Assessment and Chemoprevention of HZE-Induced CNS Damage. M. Vazquez (PI)	NT2 human neural stem cells, oligodendrocytes	Survival, apoptosis, gene expression.
B-66	ALTEA – MICE: Effects of transient heavy ion radiation on the electrophysiology of the mice visual system L. Narici (PI)	C57Bl/6 mice and active detectors	CNS damage, electrophysiological changes in the mice visual system .
B-73	DNA damage clusters in low level radiation responses of human cells. B. Sutherland (PI)	T7 DNA, Human monocytes Supercoiled DNA	DNA damage cluster induction and repair at the molecular and cellular levels
N-88	Complex Space Radiation-induced DNA damage Clusters in Human Cell Transformation: Mechanisms, relationships and Mitigation. B. Sutherland (PI)	Human normal fibroblasts	DNA damage cluster and transformation
N-89	Induction of Bystander Effects by High LET Radiation in Cells K. Held (PI)	Human keratinocytes and fibroblasts	Micronuclei formation, expression of p21 and foci formation of γ H2AX
N-91	Repair of HZE-induced DNA Double Strand Breaks and PCC Breaks. B. Rydberg (PI)	HeLa cells, CHO cells and xrs6 cells	DSB determination, PCC and bystander effects
N-95	Gene Expression Profile Analysis. M. Story (PI)	Human fibroblast cell lines	Gene expression by microarray studies
N-99	Transformation of hTERT-immortalized human bronchial epithelial cells by high energy heavy ions C. Zhao (PI)	hTERT-immortalized human bronchial epithelial cells. Mouse embryonic fibroblast (MEF) cells.	The clonal cells in soft agar will be expanded and inoculated into nude mice. The transformed cells at each stage of neoplastic process will be characterized. Colony formation.
N-103	Mechanism of HZE Damage and Repair in Human Epithelial Cells M. Barcello-Hoff (PI)	2D and 3D HMEC cultures.	1. DSBs induction and rejoining; 2. gene expression and 3. survival.
N-104	Radiation Leukemogenesis M. Weil/R. Ullrich (PI's)	CBA/CaJ strain mice	Determination of RBE for the induction of AML using slope constants.

Exp.	Participants	Samples	Endpoints
N-113	The Effects of Charged Particle Radiation on the CNS Response to an Immunological Stressor. M. Pecaut (PI)	C57BL/6	Histological Analysis of the hippocampus
N-118	Intercomparison of Space Radiation Detectors J. Miller (PI)	Wide variety of passive and active detectors	Ground-based intercomparison of various radiation instruments and detectors that are being used to measure the radiation exposure of crews aboard the International Space Station (ISS) and the Space Shuttle
N-121	HZE Upgrade and Verification of 3-D Transport Code M. Moyers (PI)	measure the charge produced in an air-filled ionization chamber as a function of depth within a water-filled phantom along the central axis of an ion beam	The first set of experiments will test the calculation of ion stopping powers for a material, energy deposition in the material, and production of large range secondary particles. The second set of experiments will test the calculation of the angular scattering power for a material and the angular distribution of long range secondary particles
N-122	Gene Expression in the Nematode <i>C. Elegans</i> Following Irradiation with Charged Particles. G. Nelson (PI)	Nematode <i>C. elegans</i>	Gene expression by microarray studies
N-123	Submicron Resolution Detector Studies V. Radeka (PI)	Silicon active particle detector and CR39 passive plastic detector	Detector position resolution and linearity measurements. Correlation of a plastic detector and the silicon detector.
N-124	HZE particle induced genetic instability/ oncogenic transformation and their prevention C. Li (PI)	10T1/2, mouse embryonic fibroblast cell lines, <i>CADKO</i> cell line, a mouse embryonic fibroblast with deficiency in apoptosis	Strand-breaks as indicated by immunohistochemistry staining of the phosphorylated H2AX protein. Chromosomal aberrations Frequency of mutations at the drug-selectable HPRT locus.
N-126	Effects of L-Selenomethionine and other Agents on HZE Particle Radiation Induced Cell Killing and Malignant Transformation in vitro. A. Kennedy (PI)	Htori-3 cells (Human Thyroid Epithelial Cells)	Radioprotective effects of L-selenomethionine (SeM), immunofluorescence assays, colony formation
N-128	NASA Space Radiation Summer School M. Vazquez	NT2 and TK6 cells, C57Bl/6 mice, films and plastic particle detectors	Cell survival, apoptosis, DNA damage, micronuclei formation, hematological changes, track structure studies.

List of personnel that participated in the planning, organization and execution of NSRL-3 run

BNL Management:

- Laboratory Director: **Praveen Chaudhari**
- Associate Director for High Energy and Nuclear Physics: **Tom Kirk**
- Associate Laboratory Director for Life Sciences: **Helene Benveniste**

NASA Management:

- Headquarters: **Walter Schimmerling, David Tomko**
- JSC: **Frank Cucinotta, Frank Sulzman, Barbara Corbin**

Scientific Advisory Committee:

- **Betsy Sutherland** (Chair), BNL
- **Louis Pena**, BNL
- **Richard Setlow**, BNL
- **Kathy Held**, MIT
- **Les Braby**, PNL
- **Charles Geard**, Columbia University

Collider Accelerator Department-AGS

- Chairman: **Derek Lowenstein**
- Deputy Chairman: **W.T. Weng**
- Associate Chair of Operations: **A.J. McNerney**
- Experimental Planning and Support Head: **Philip Pile**
- Associate Chair for ESHQ: **Ed Lessard**
- ESHQ Division Head: **Ray Karol**
- ESH Coordinator: **Asher Etkin**
- Facility Support Representative: **Chuck Schaefer / Henry Kahnhauser**
- Environmental Coordinator: **Joel Scott**
- Training and Procedures Manager : **John Maraviglia**
- Main Control Room: **Peter Ingrassia**
- Work Control Manager: **Peter Cirnigliaro**
- BNL Laser Safety Officer: **Chris Weilandics**
- Experimental Safety Review Committee: **Yousef Makdisi (Chair)**
- Radiation Safety Committee: **Dana Beavis (Chair)**
- Accelerator Safety Review Committee: **Woody Glenn (Chair)**
- ALARA Committee: **Chuck Schaefer (Chair)**
- Associate Chair for ES&H/Q.A: **E. Lessard**
- Accelerator Division Head: **Thomas Roser**
- Chief Electrical Engineer: **J. Sandberg**

- Chief Mechanical Engineer: **J. Tuozzolo**
- Accelerator Physicist lead by: **Leif Aherns**
- Tandem Group leader: **Peter Thieberger**
- Physics Support: **Yusef Makadisi**
- CAD Components and instrumentation support: **David Gassner**
- AGS Radiation Safety Committee: **Ken Reece**
- C-A Dept Training Manager: **John Maraviglia**
- AGS Control Section lead by: **Don Barton**
- Liaison Engineering Group lead by: **David Phillips**
- Liaison physicist: **Adam Rusek**
- RHIC&AGS Users Center: **Susan White-DePace, Angela Melocoton**
- Mechanical Service Technicians led by: **Fred Kobasiuk**
- Survey Group led by: **Frank Karl**
- Beam Service Technicians led by: **Paul Valli**
- Electronic Service Technicians led by: **Bill Anderson**
- AGS Instrumentation Group led by: **Pete Stillman**
- AGS Main Control Room and Operations led by: **Pete Ingrassia**
- **AGS MCR Operation Coordinators:**
 - Jim Jamilkowski**
 - Greg Marr**
 - Sanjee Abeytunge**
 - Jennifer Kozak**
 - Brian van Kuik,**
 - Travis Shrey**
- AGS Electricians led by **Bill Softye**
- AGS Riggers led by: **Nick Cipolla**
- Carpenter and Welder Support Service and Technical Support led by: **Roger Hubbard**

Dosimetry:

- **Don Lazarus**
- **Adam Rusek**
- **I-Hung Chiang**
- **Kin Yip**
- **Peter Oddo**
- **Bart Frank**

Medical Department:

NASA LTSF TEAM:

- **Medical Liaisons: Marcelo E. Vazquez, Peter Guida**
- **Technical support: Bea Pyatt, Stacey Russell, Adele Billups**
 - Dept. Chair: **Helene Benveniste**
 - Building Manager: **Chris Harris**
 - Administration: **Denise White and Donna Russo**
 - Animal Care Facilities: **Maryann Kershaw, Kerry Bonti, Patricia Leone**
 - Training Coordinator: **Ann Emrick**
 - **RCD**
 - Kay Conkling
 - Dennis Ryan
 - Deana Buckallew
 - Jim Williams
 - Bob Colichio

Plant Engineering:

- BLAF Custodian, **P. Abrams**
- Plumbers: **B. McCafferty**
- Painters/Carpenters: **B. Laakmann**
- Electricians: **T. Baldwin**

Biology Department:

- Chairman: **Carl Anderson**
- Biology Liason: **Betsy Sutherland**
- Technical Support: **Mamta Naidu, Debasish Roy**
- Cesium Source Manager: **Richard Sautkulis**